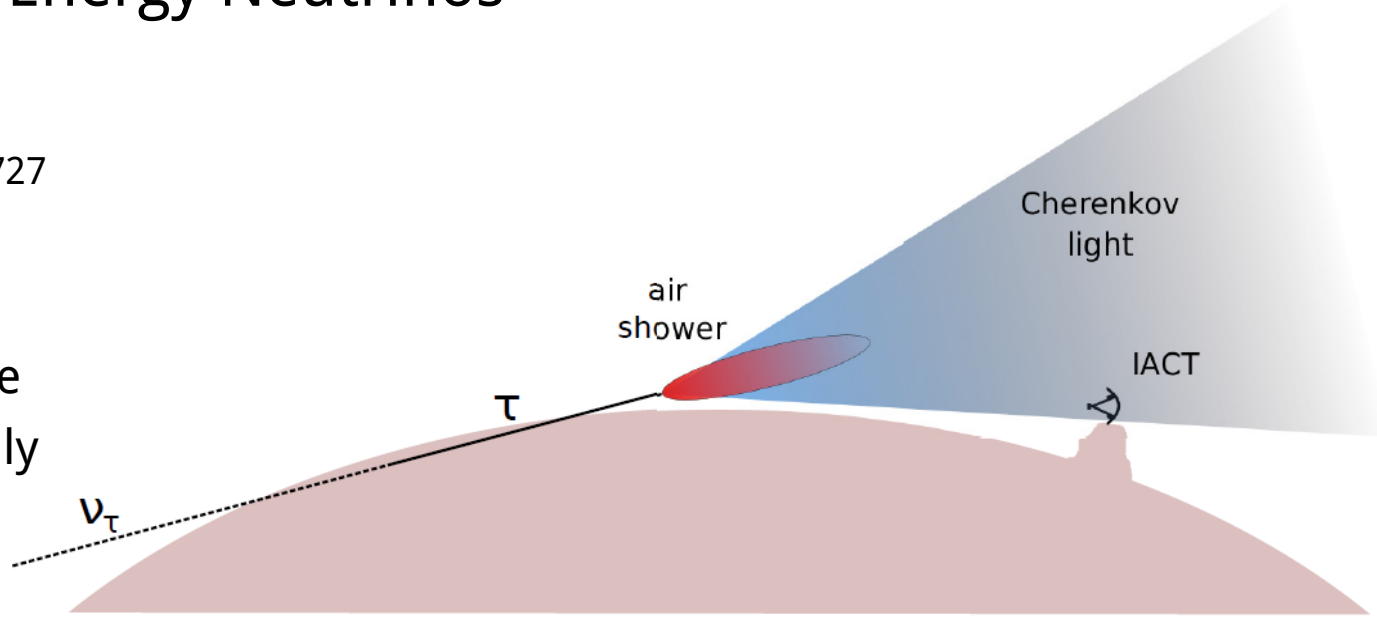
Trinity

An Air-Shower Imaging System for the Detection of Ultrahigh Energy Neutrinos

Phys. Rev. D 99, 083012 (2019)
and
Astro2020 white paper arXiv:1907.08727

Anthony Brown, Durham, UK
Abraham D. Falcone, Penn state
Mosè Mariotti, Uni. Padova, Italy
Ignacio Taboada, Georgia Tech

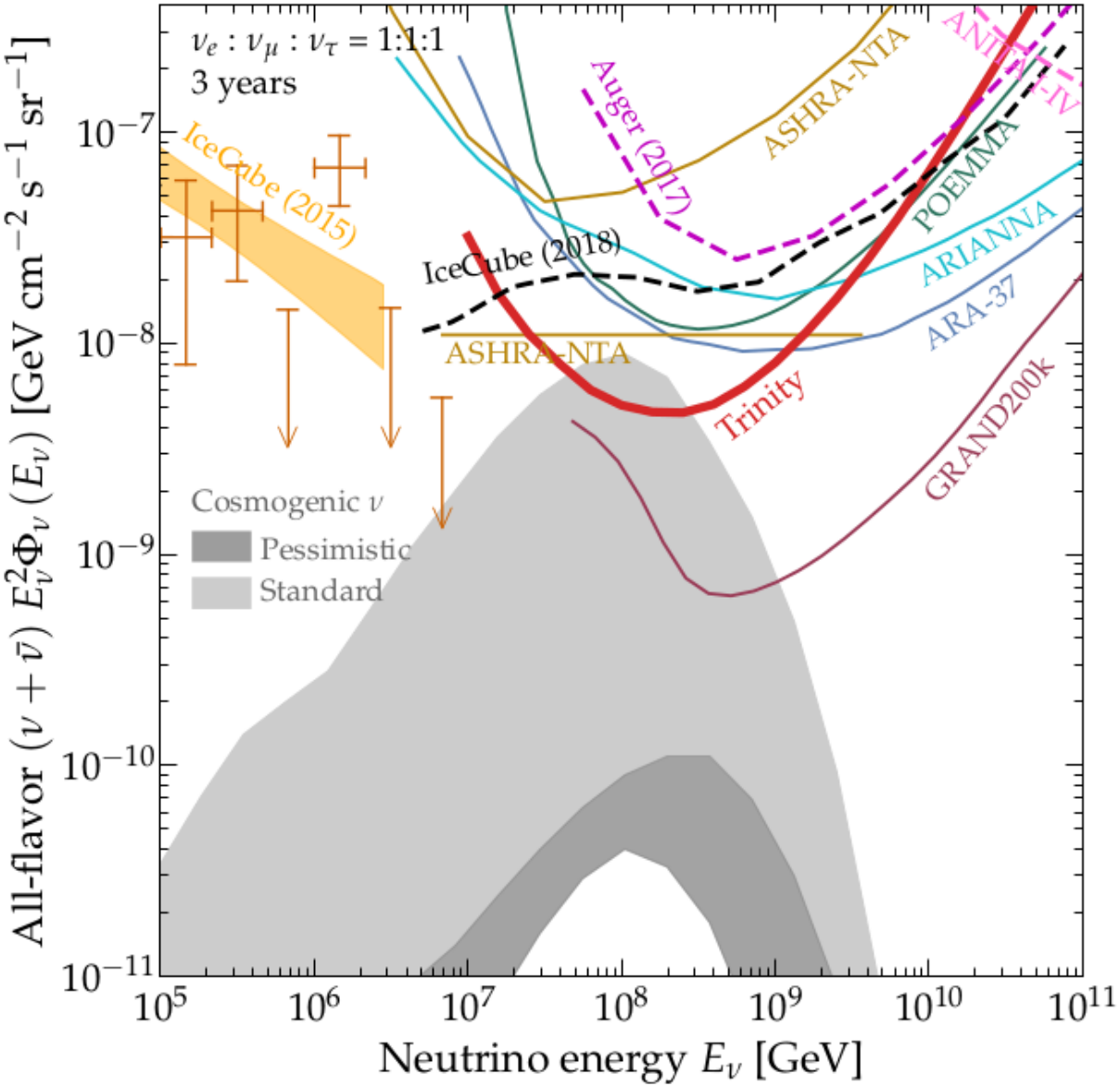


Nepomuk Otte

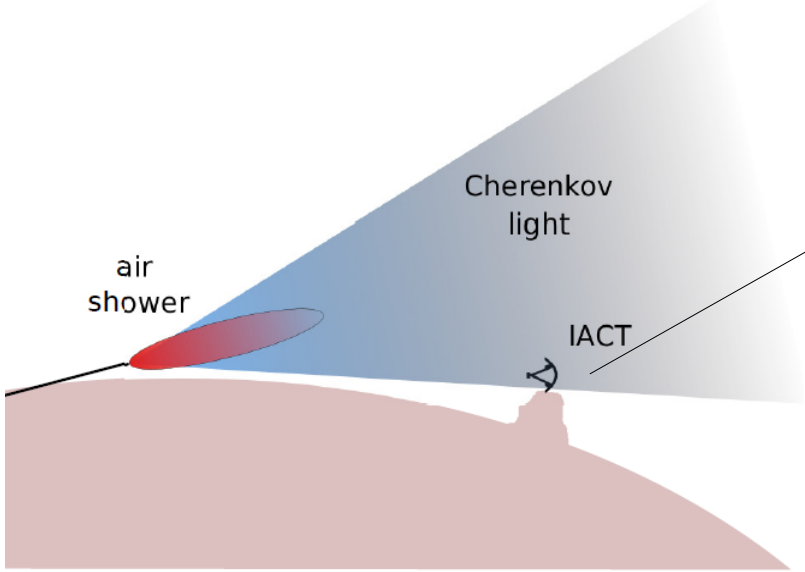
School of Physics
&
Center for Relativistic Astrophysics

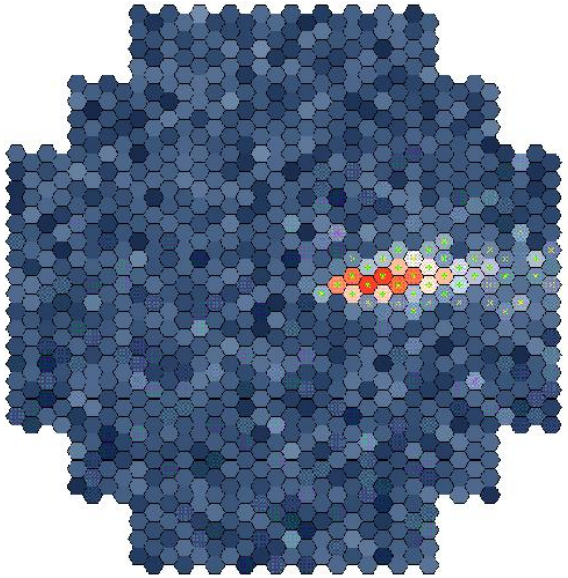
Georgia Tech Physics College of Sciences

Three year sensitivity



Air-Shower Imaging



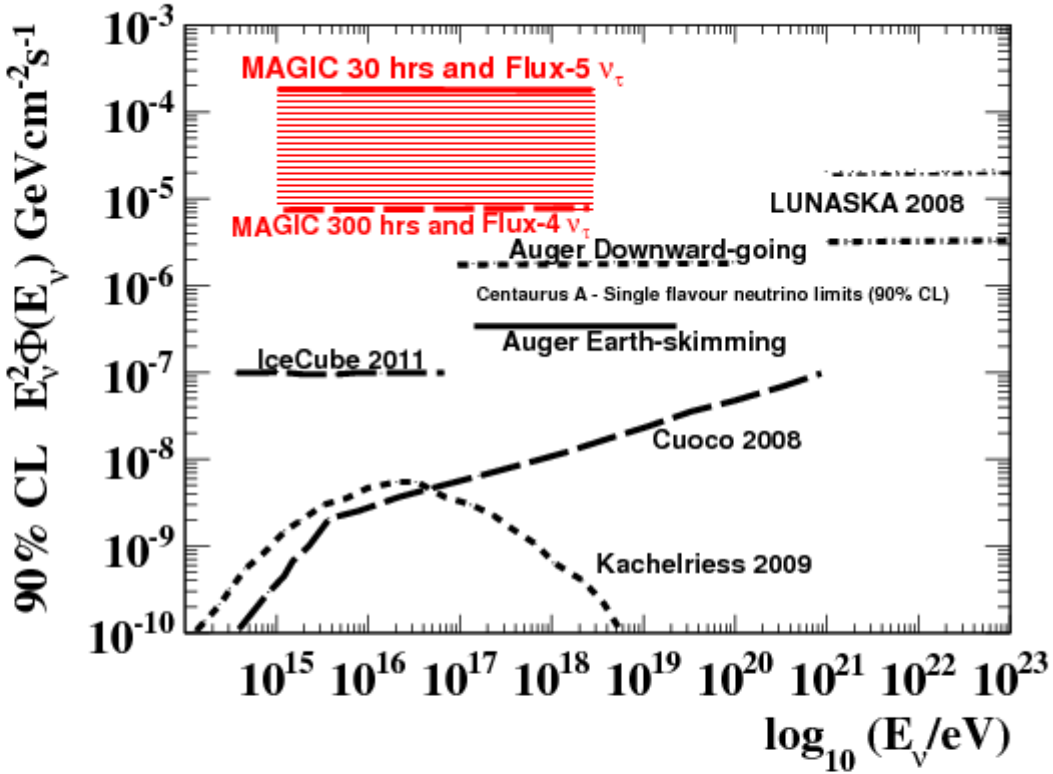


Proven Technique

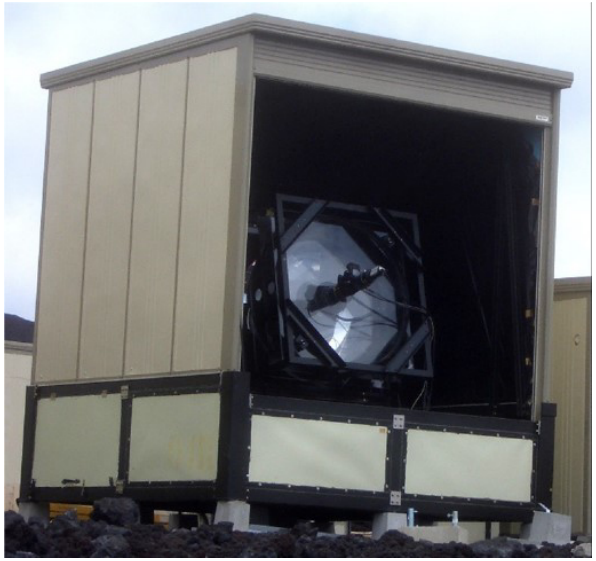
- Angular resolution ~0.1°
- Energy resolution ~10%
- Excellent background suppression

UHE Neutrino Searches with Air-Shower Imaging Telescopes

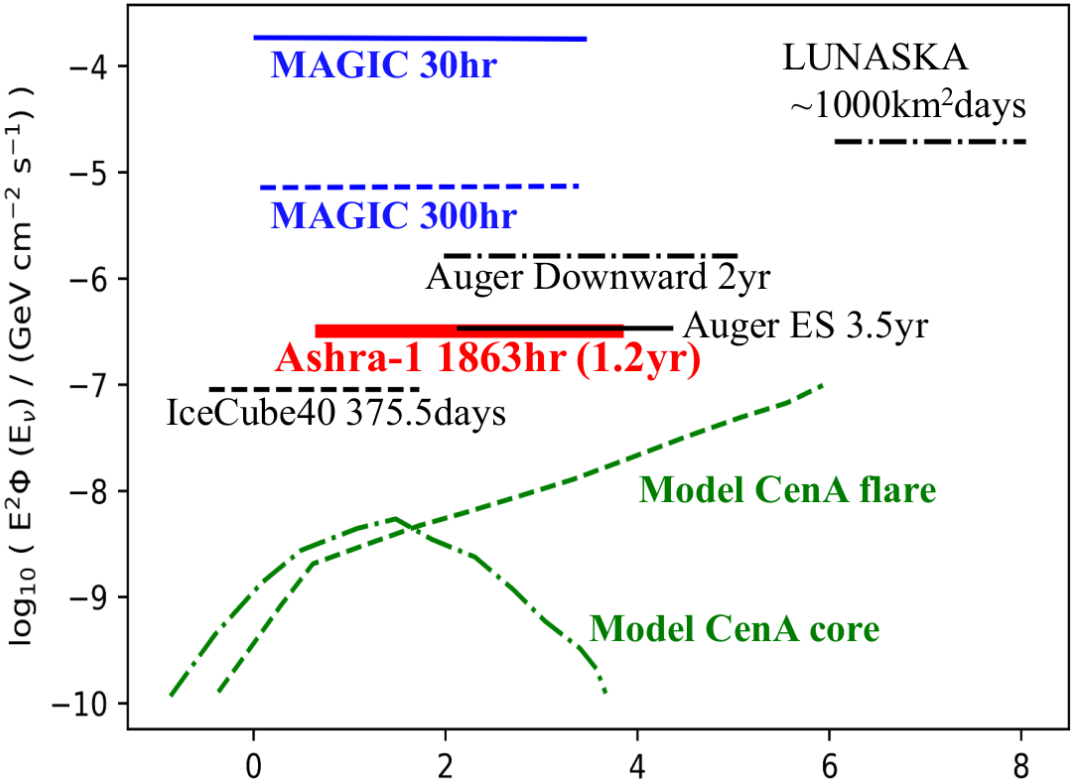
MAGIC (2018), Astropart.Phys.102,77-88.



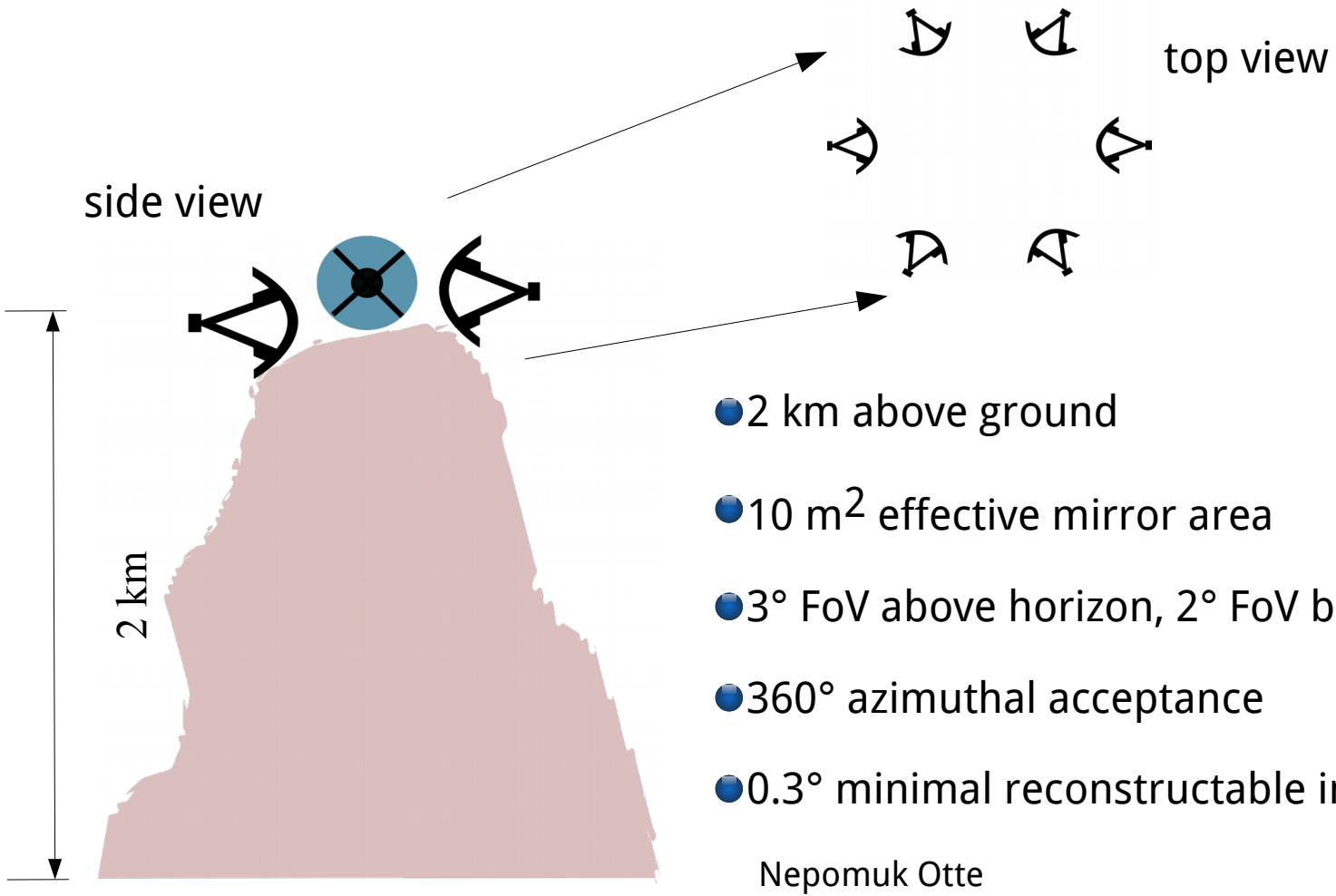
UHE Neutrino Searches with Air-Shower Imaging Telescopes



Ashra-1 PoS(ICRC2019)970

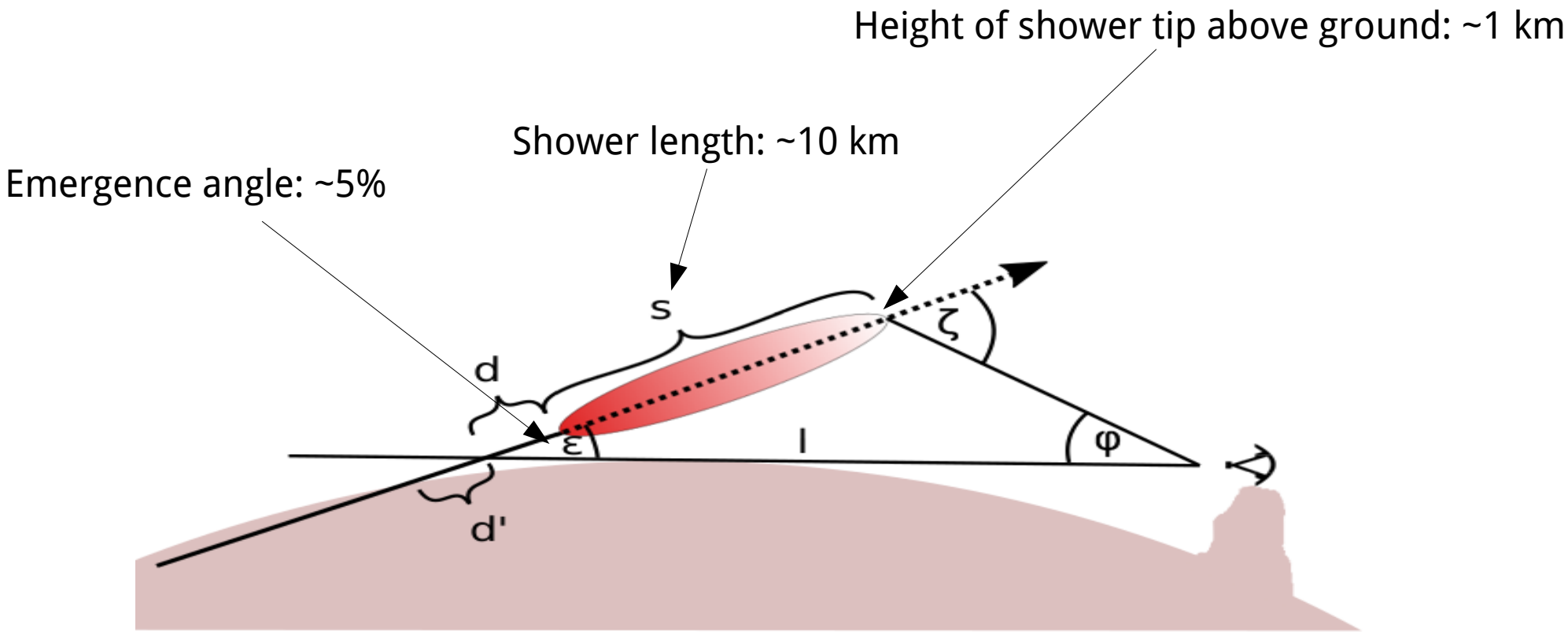


Trinity: Baseline Configuration

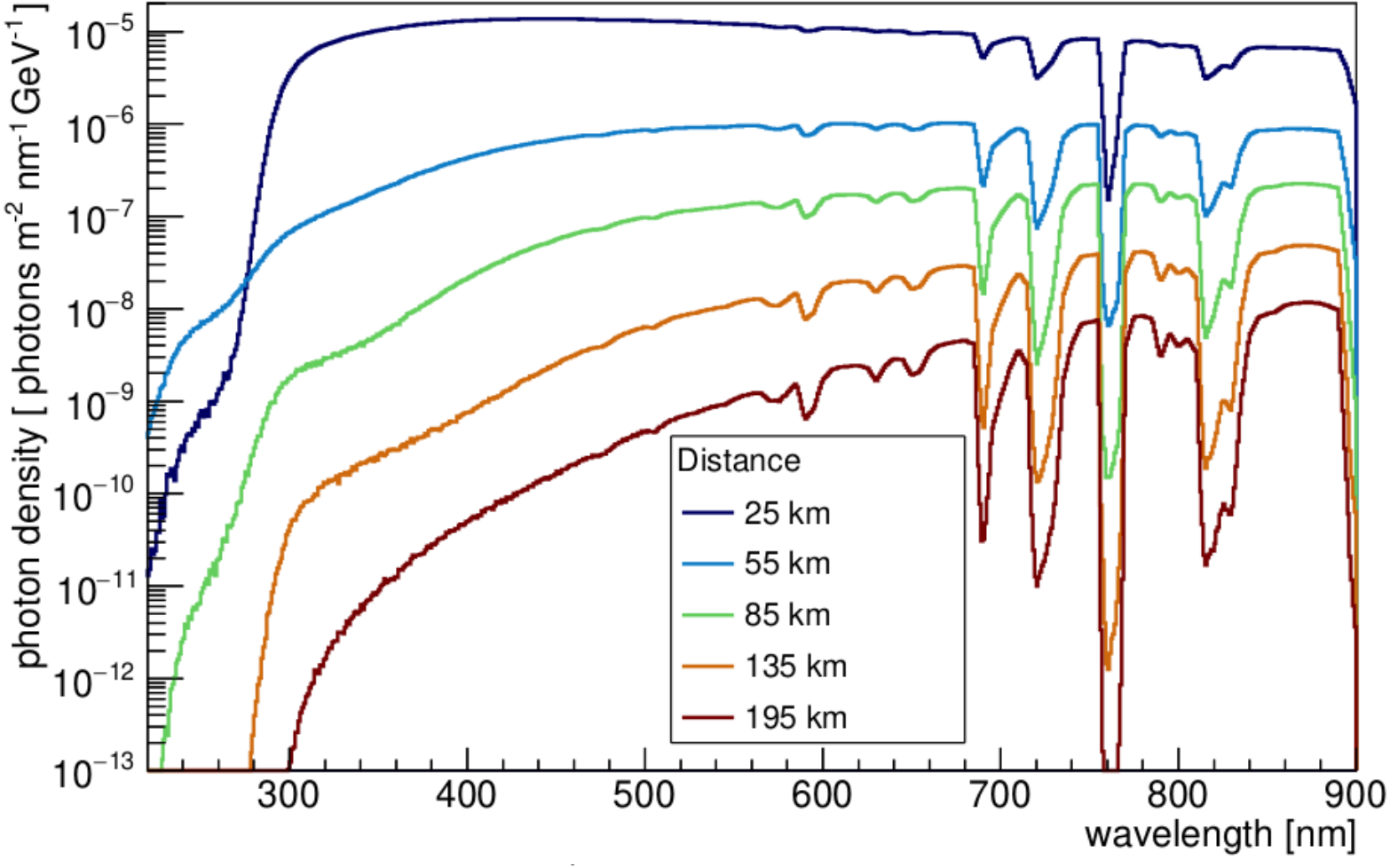


- 2 km above ground
- 10 m^2 effective mirror area
- 3° FoV above horizon, 2° FoV below horizon
- 360° azimuthal acceptance
- 0.3° minimal reconstructable image length

UHE Tau initiated Air-Shower Fun Facts

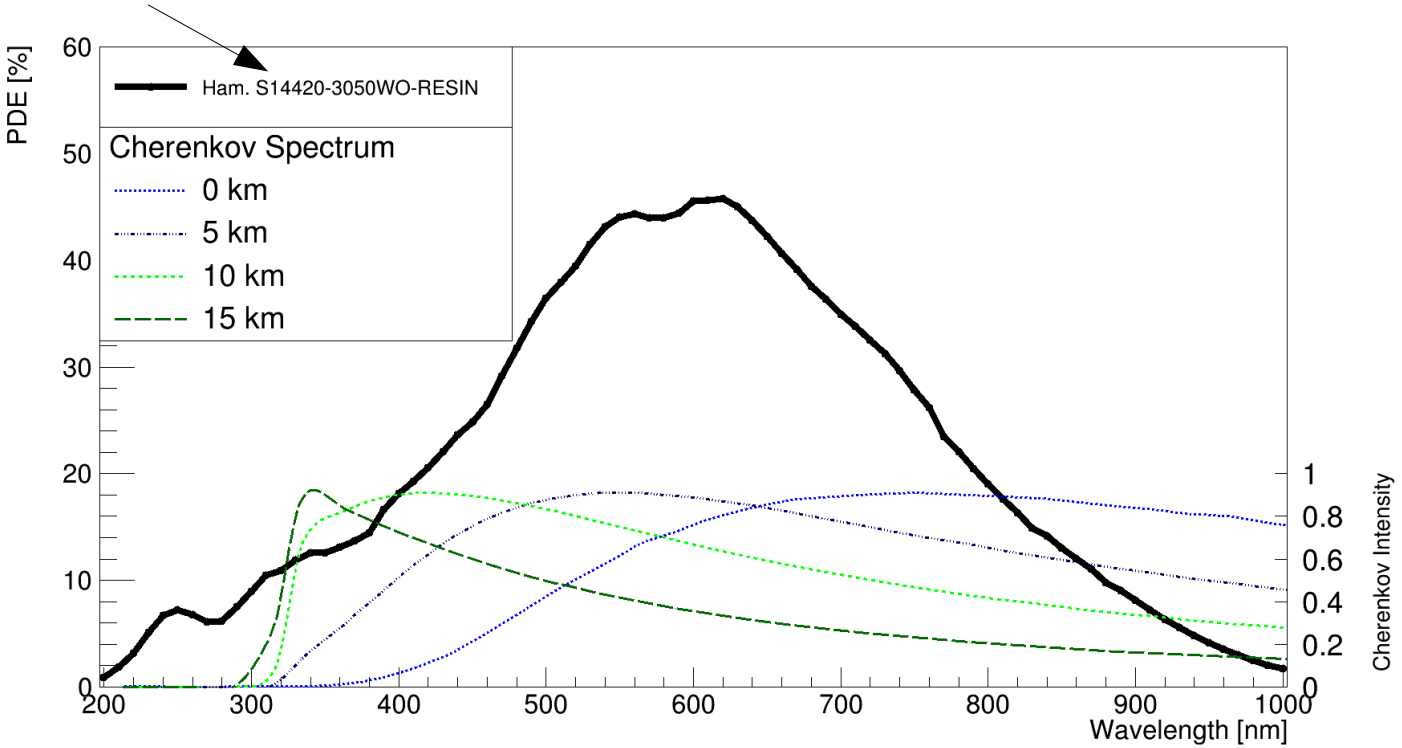


Air Showers for Lovers



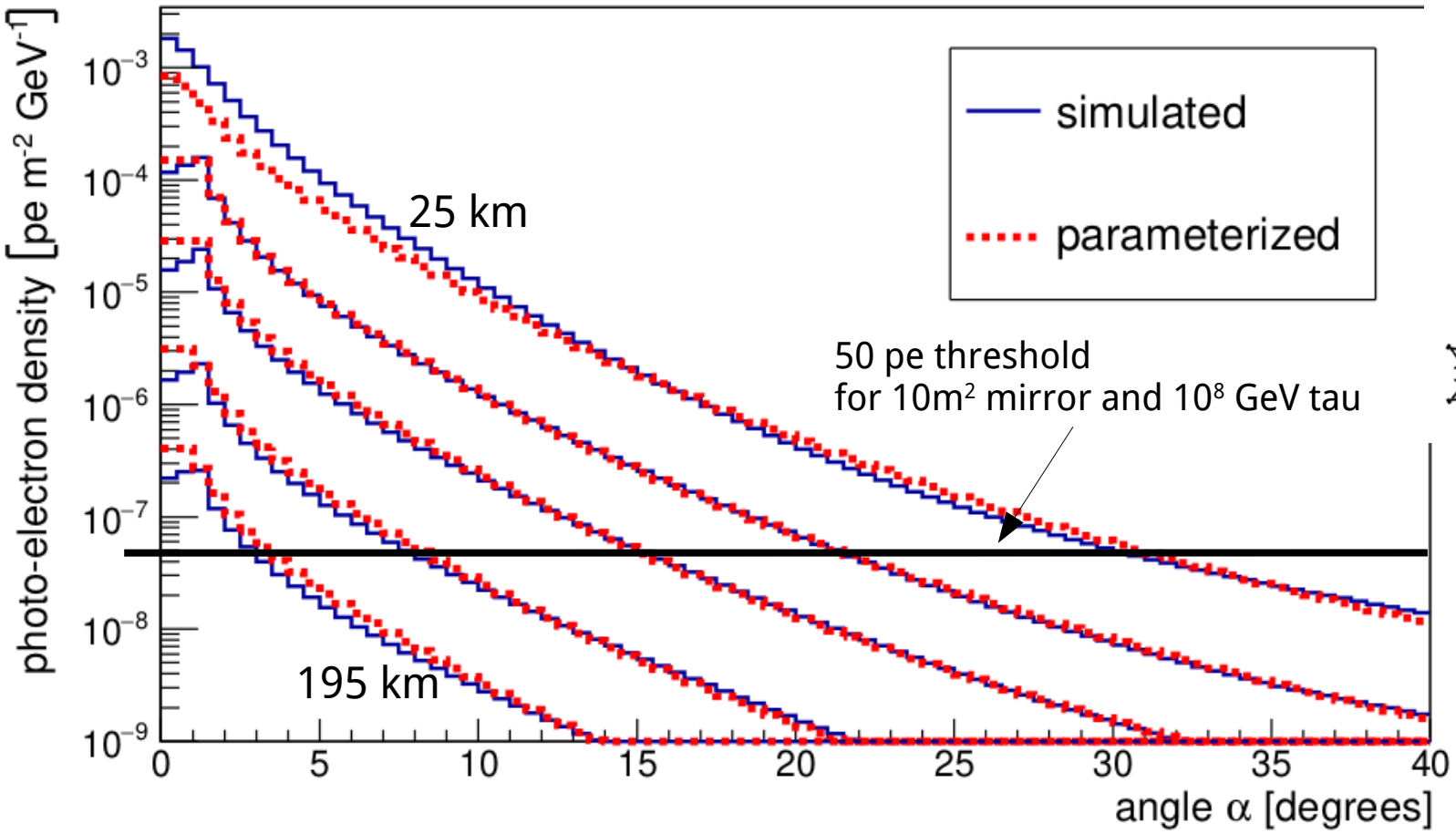
Red Sensitive Silicon Photomultipliers

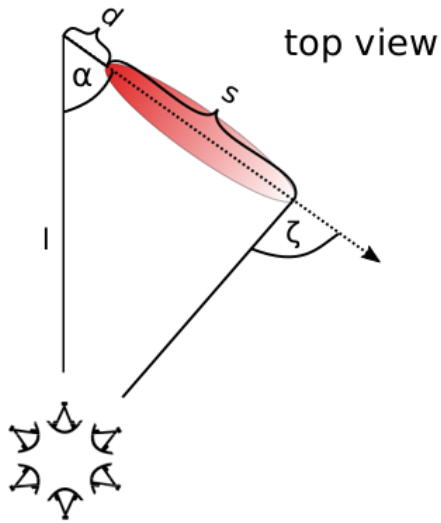
Hamamatsu S14420



NO et al. EUSO-SPB2 PoS(ICRC2019)977

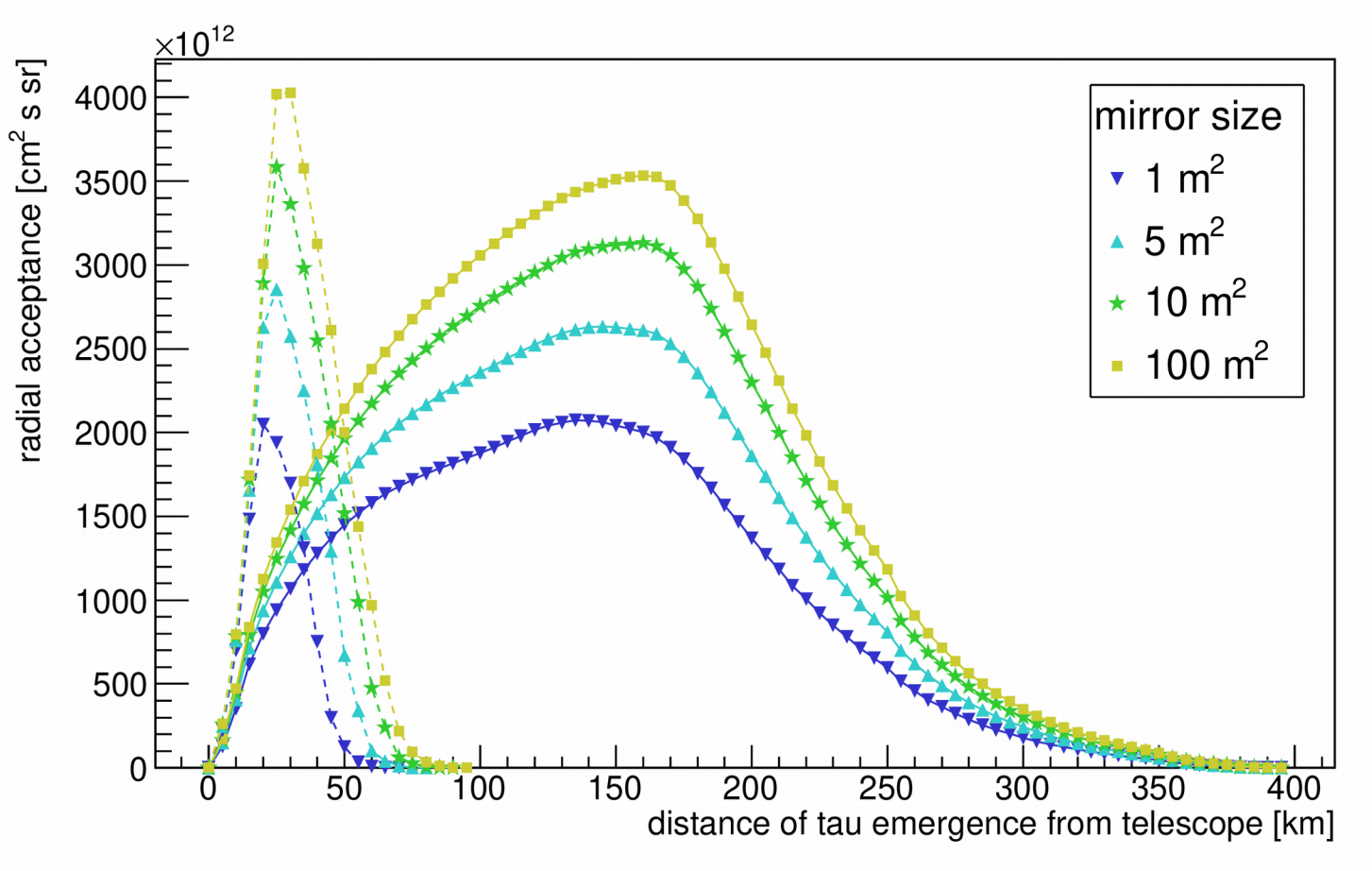
Detected Cherenkov Light



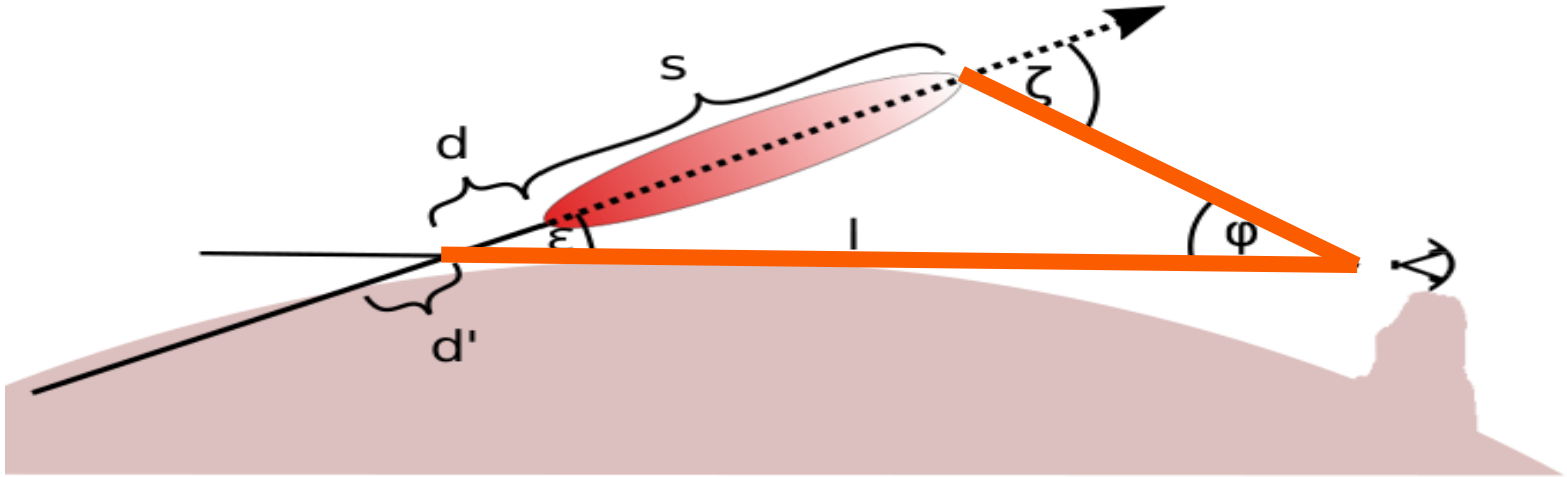


Calculated with PDE of Hamamatsu S14520

Acceptance vs. Light Collection Area

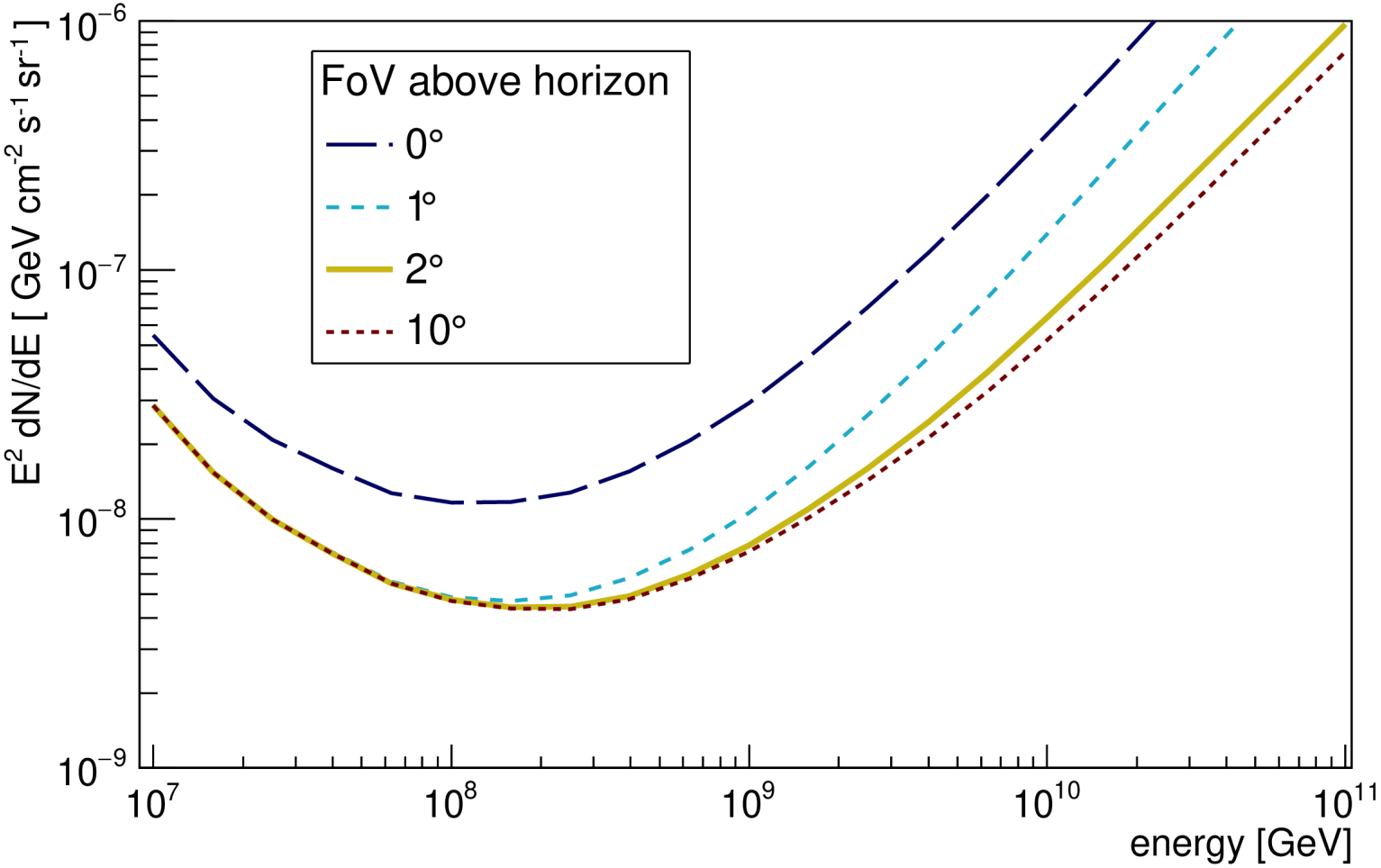


How much Field of View?

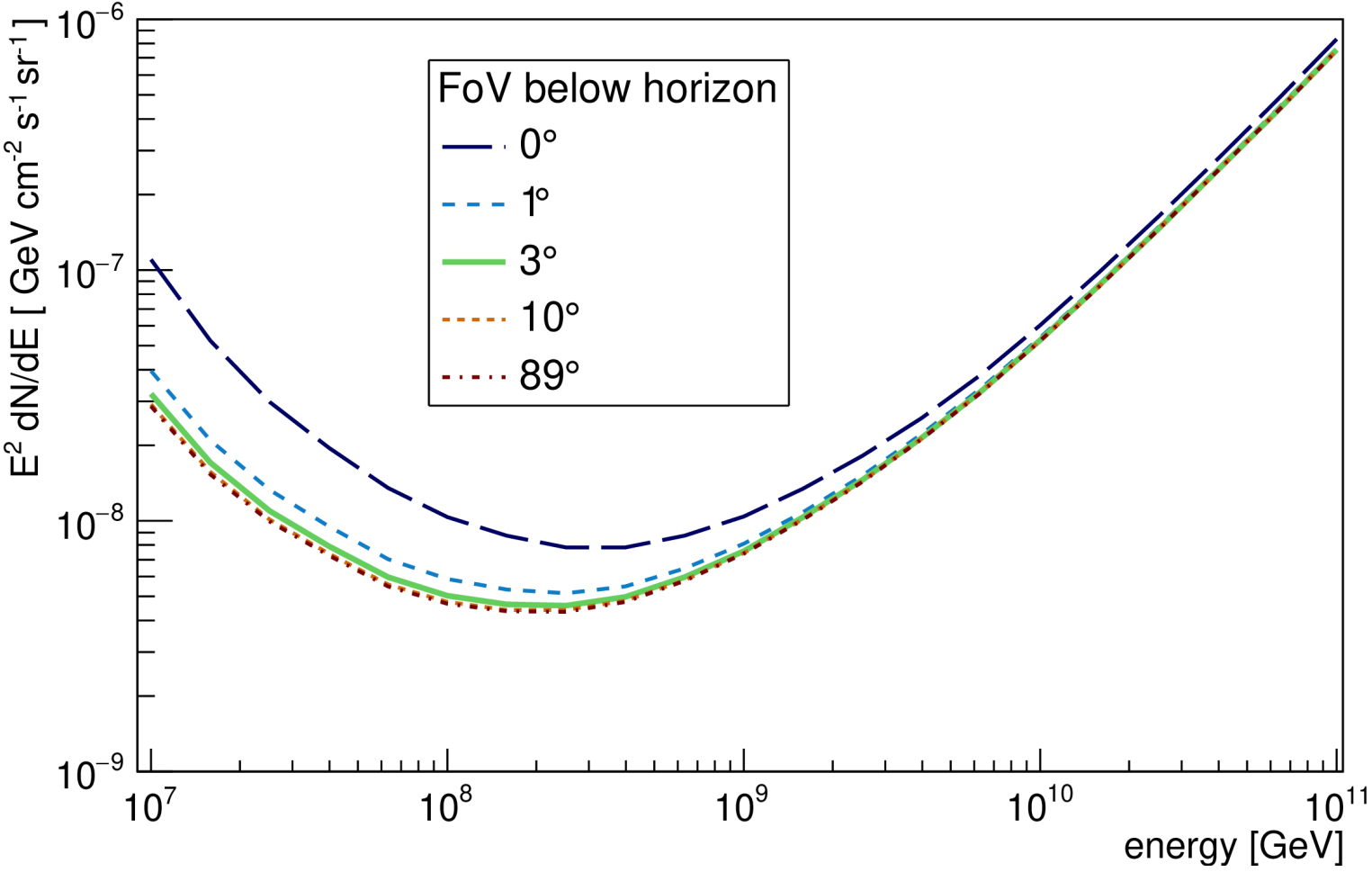


Full image containment is required.

Sensitivity vs. FoV above Horizon



Sensitivity vs. FoV below Horizon

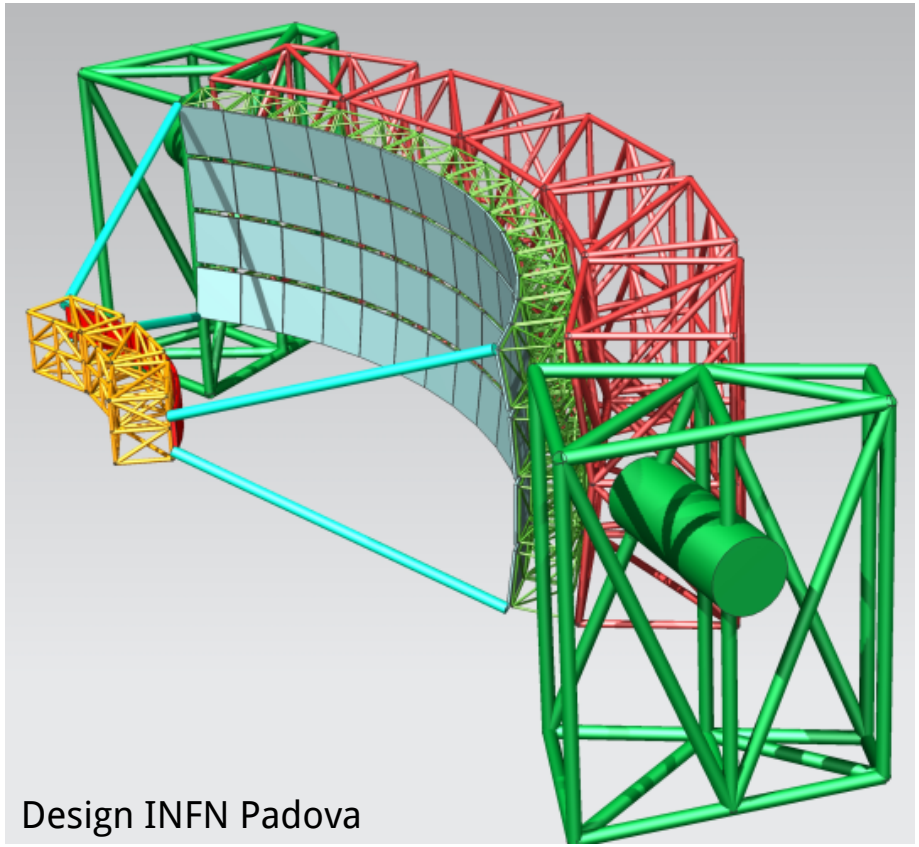



PREF
+031.69168° / -110.88498° 8436ft 13:15:52
MAIL
POSITION - ALTITUDE - TIME
MAP
LOG
1° veto region
4° signal region
HORIZON
+00.8°
ANGLE
ELEVATION
-01.9°
ANGLE
AZIMUTH - BEARING
301° N59W 5351mils TRUE
ZERO
A-B
CAL
W
300
330
LENS
1.0 X
S

Optics

Based on J. Cortina et al., Astrop. Physics 72 (2016) 46

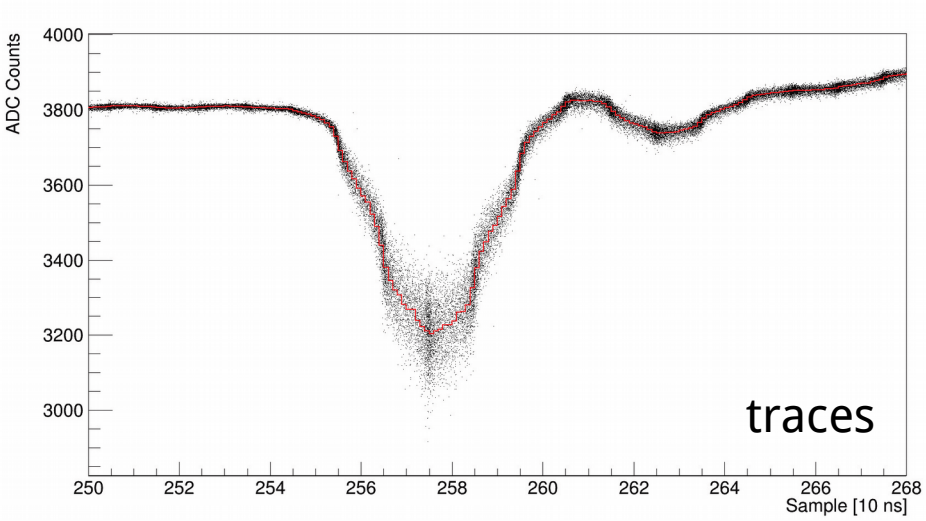
- **FoV 5° X 60°.**
- 5.6 m focal length.
- 0.3° optical PSF.
- 20 mm Winston cones coupled to **9 mm SiPMs**.
- 3,300 pixel camera.
- 68 m^2 mirror area → **16 m^2** in any direction.
- Rotates in elevation.
- Thin-glass replica mirror technology ~$2k/$m^2$.
- Implementation based on MAGIC structure.
- $170k for one telescope (excl. camera).

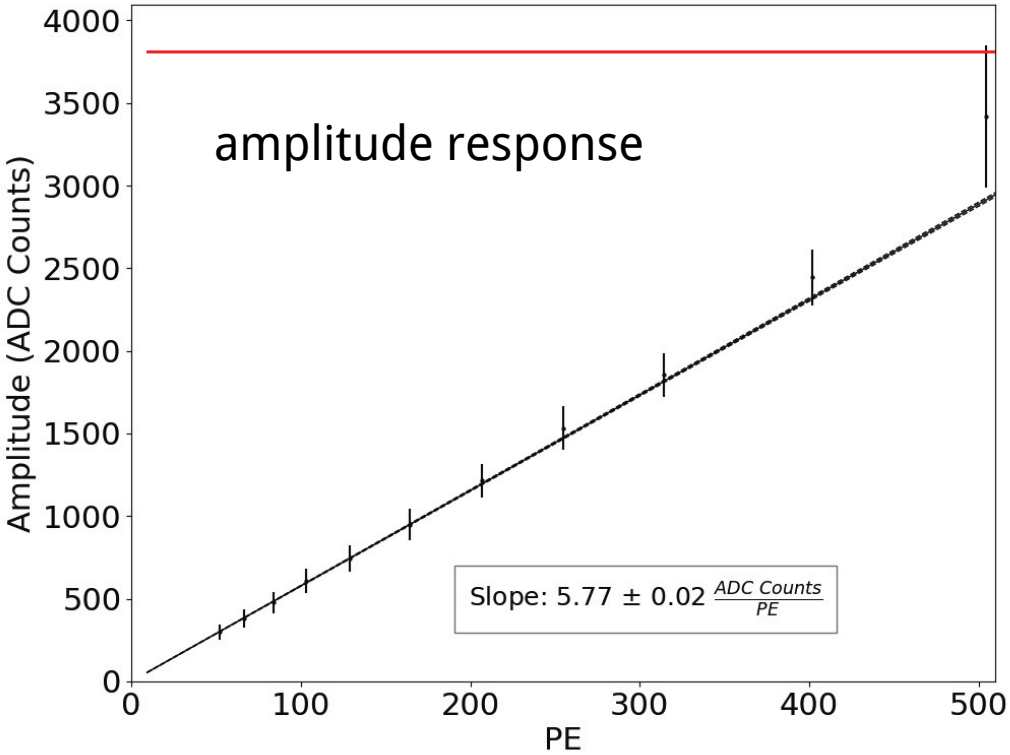


Signal Chain

Same as in NO et al. EUSO-SPB2 PoS(ICRC2019)977

- MUSIC: preamp ASIC developed for IACTs.
- AGET digitizer: 100MS/s, switch capacitor readout, 12 bit.
- $100 per channel → $330k per camera





Tested with picosecond laser flashing Hamamatsu S14520 SiPM + MUSIC + AGET

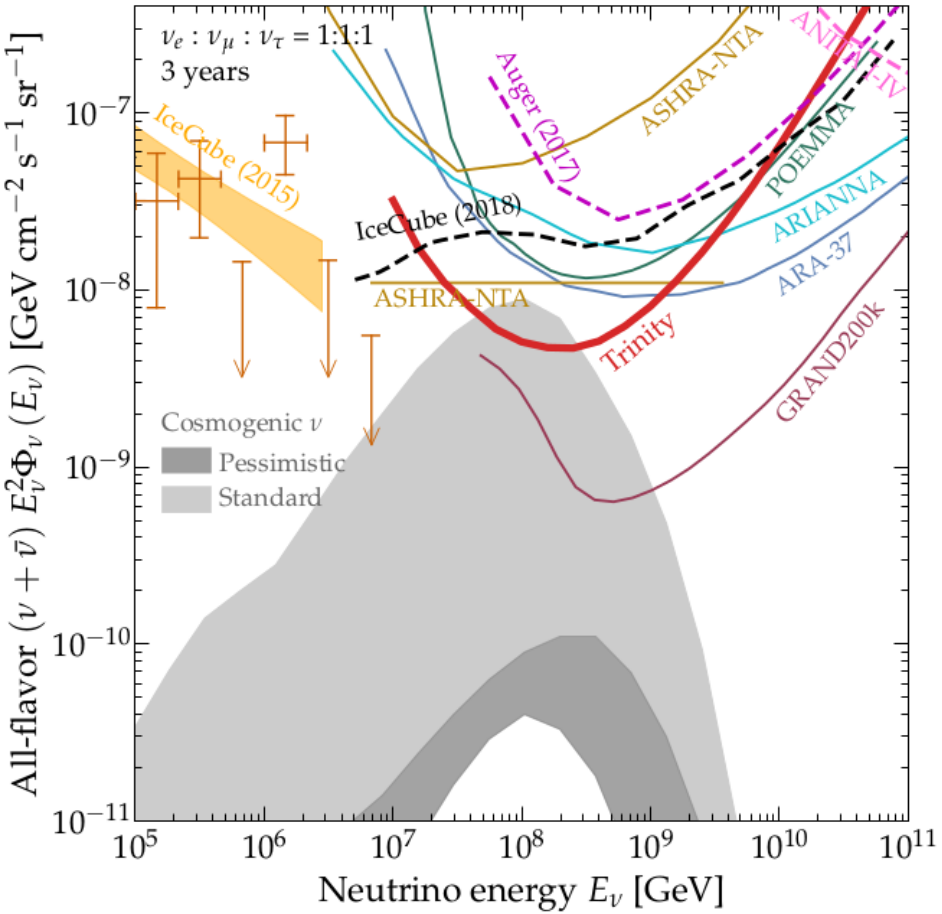
Site

- Needs to oversee a remote area.
- Modest light contamination is ok.
  - Images happen on <100ns timescales.
- Ashra Site; BEACON Test site; Frisco Peak, UT.

View from Frisco Peak, UT

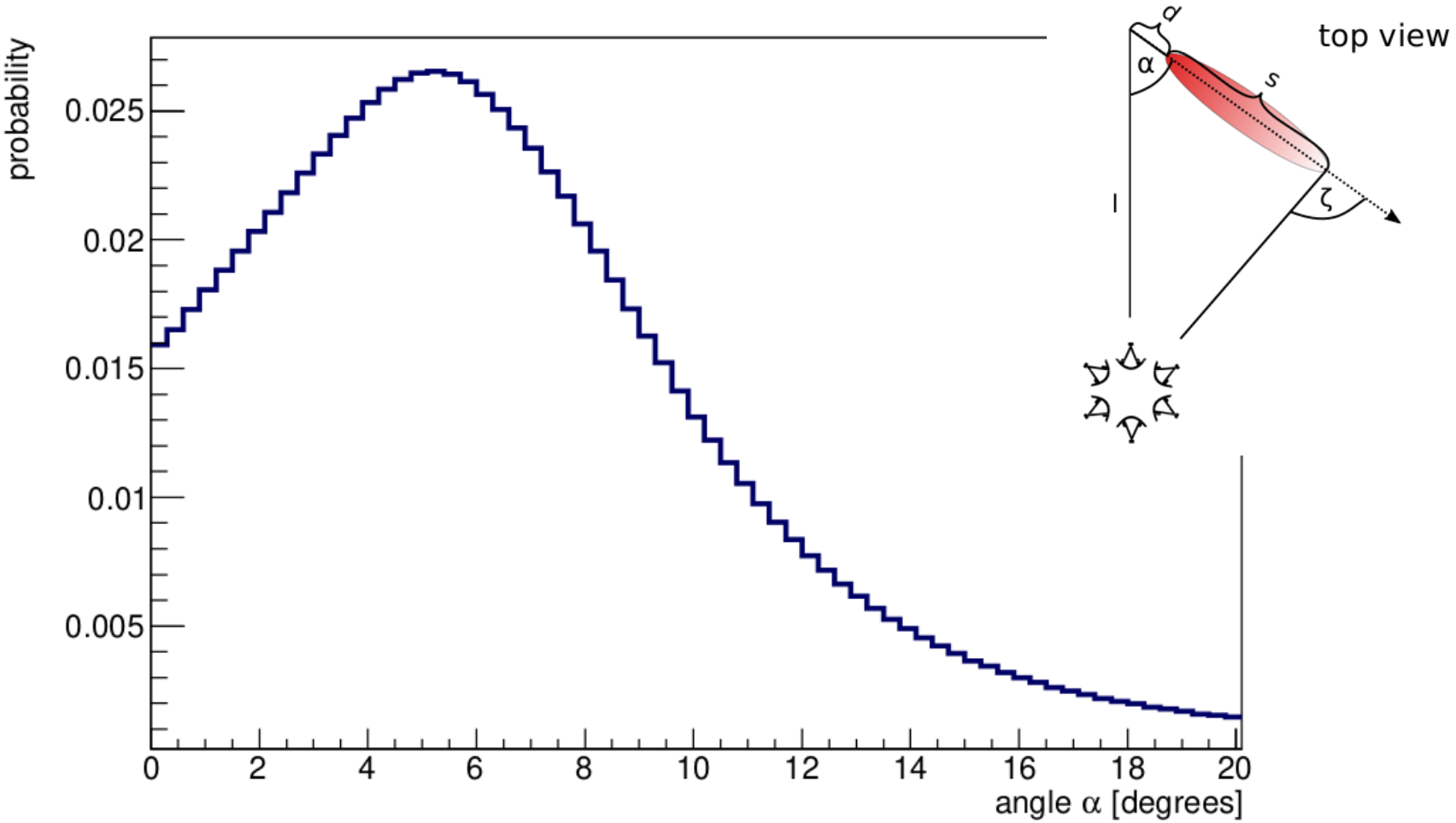
Conclusions

- Air-shower imaging is a viable technique to search for UHE neutrinos.
- Trinity is optimized to detect distant UHE tau showers.
- Cost effective solutions exist for the optics and the camera (~$3M for 360°).
- Developing of main components is ongoing.
- Deploy prototype next year?

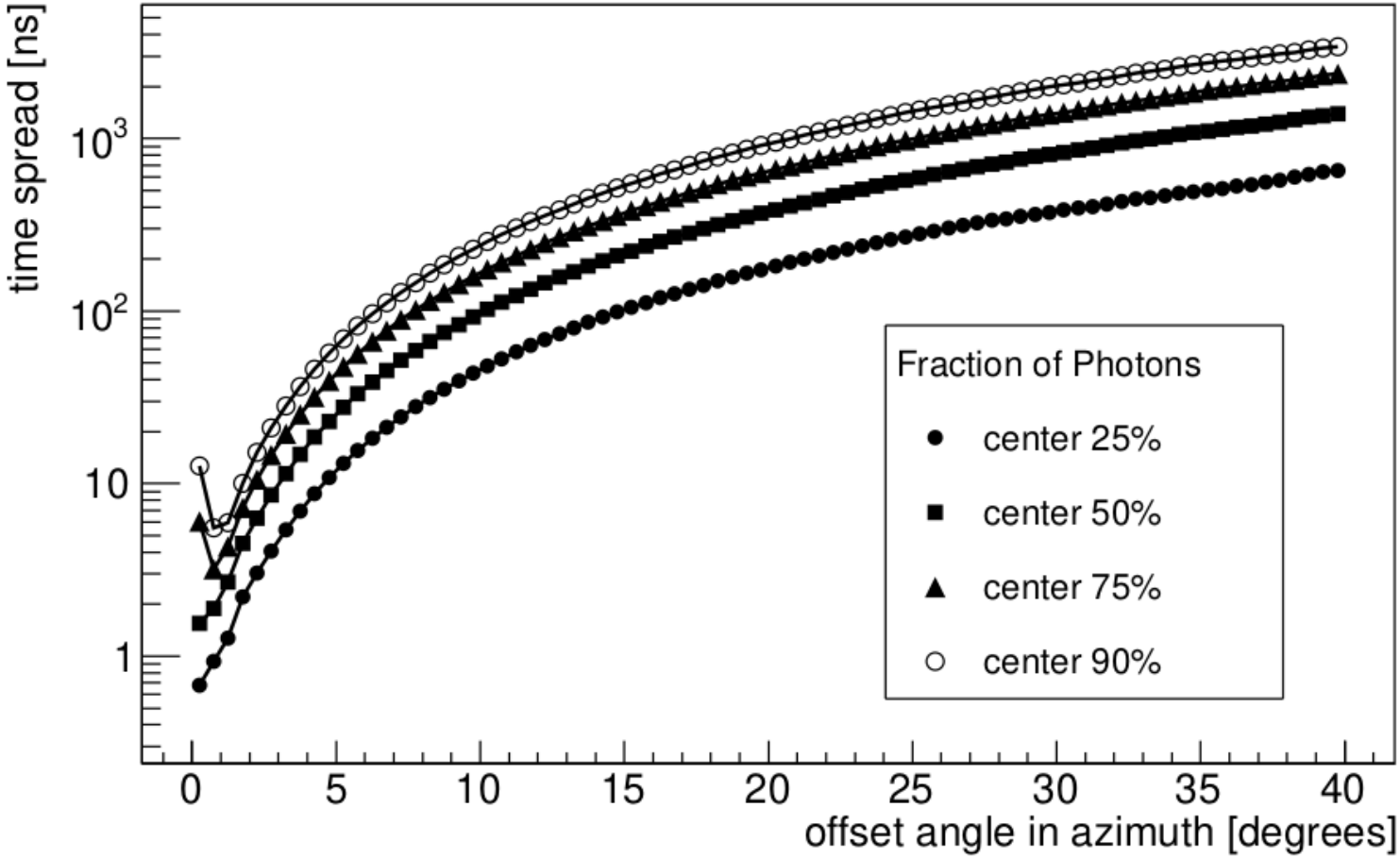


Backup

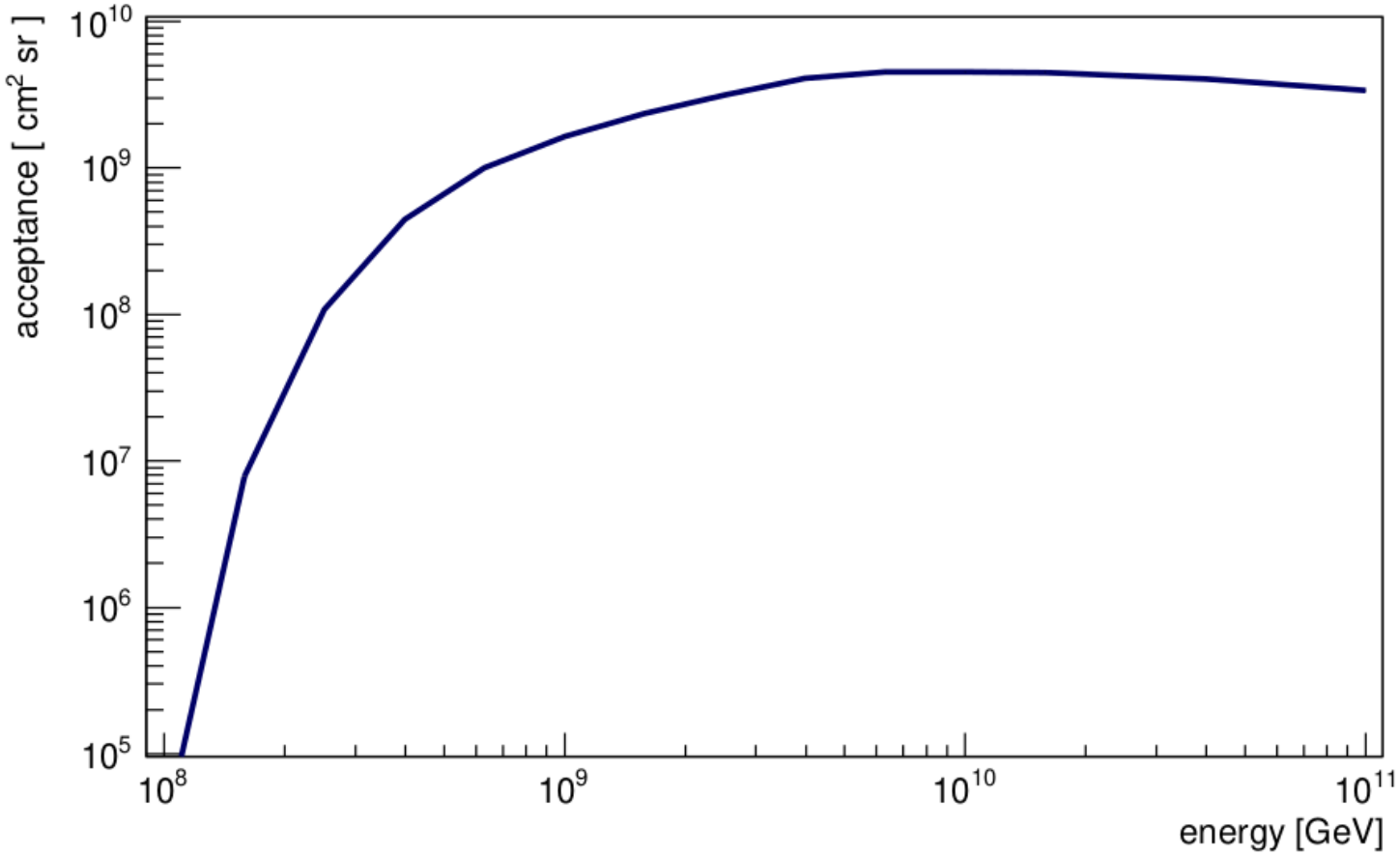
Triggered Viewing Angles



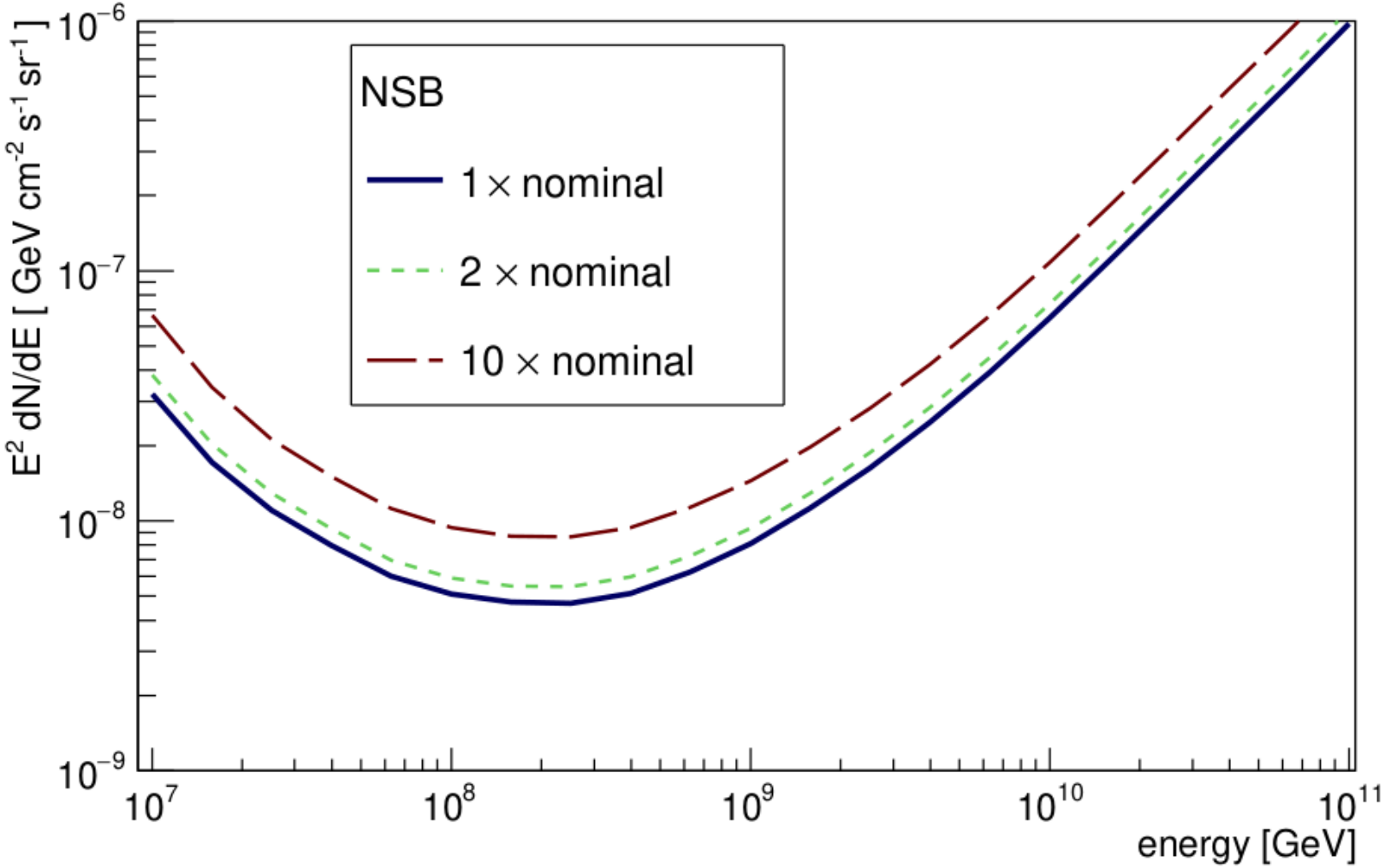
Spread of Photon Arrival Times



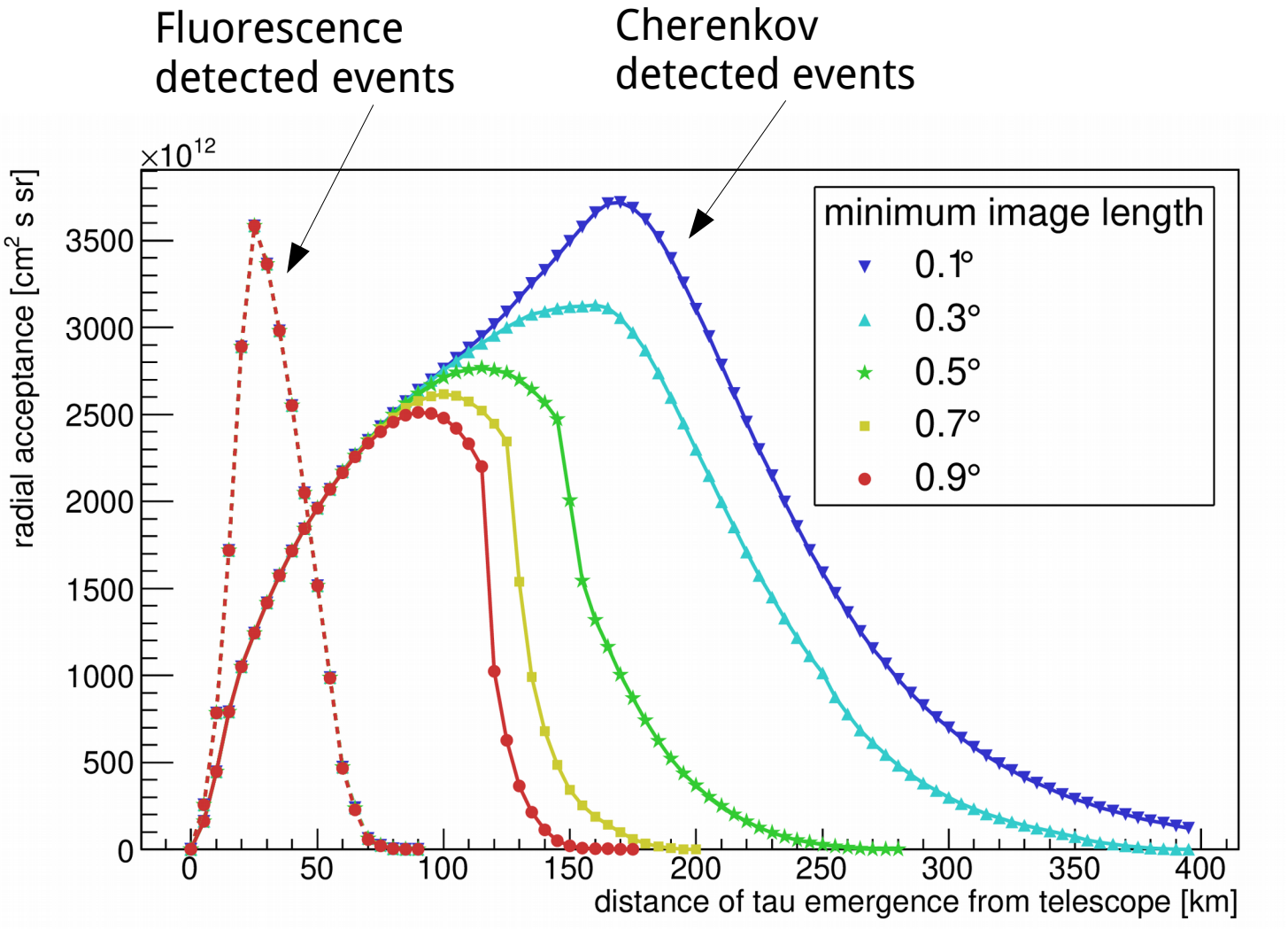
Acceptance


acceptance [cm^2 sr]
10^{10}
10^9
10^8
10^7
10^6
10^5
10^8
10^9
10^{10}
10^{11}
energy [GeV]

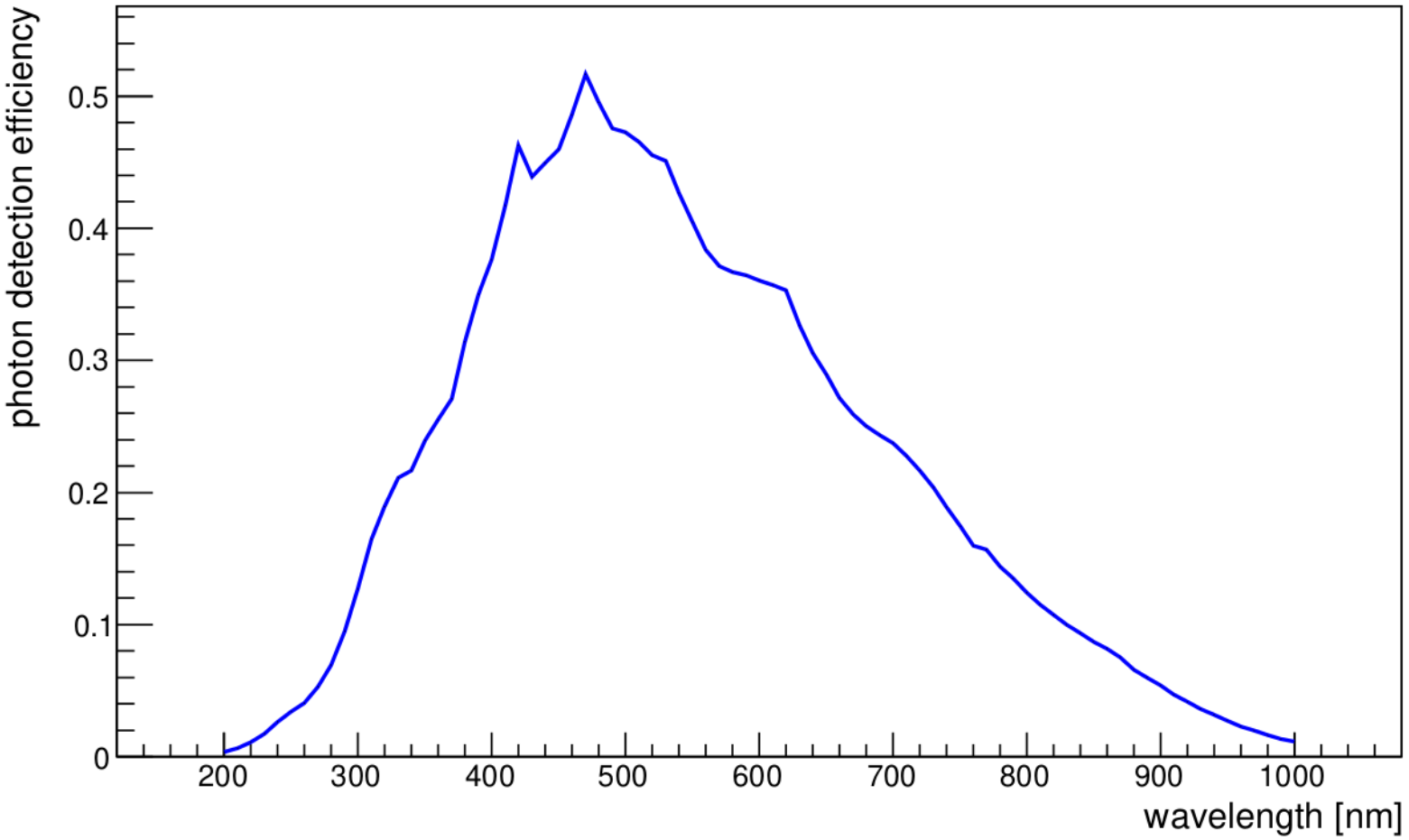
Impact of Night Sky Background



Angular Resolution



PDE Hamamatsu S14520



Thin-Glass Mirrors